Using DSCOVR EPIC as a Transfer Radiometer to Scale Multiple VIIRS Sensors Over Tropical Earth Views

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Motivation

- The CERES project currently uses Aqua-MODIS as the calibration reference in which to scale the NPP-VIIRS and N20-VIIRS to same radiometric calibration reference
  - Placing the MODIS and VIIRS imagers on the same radiometric scale facilitates consistent clouds and fluxes
- The Terra and Aqua orbits have slowly started drifting towards the terminator
  - Aqua-MODIS can no longer be used as a transfer radiometer or calibration reference between NPP-VIIRS and N20-VIIRS
- The CERES project will need to utilize other calibration/validation strategies that do not rely Aqua-MODIS to inter-calibrate NPP, N20, and future VIIRS imagers to the same radiometric scale
  - All of the JPSS orbits are in a 1:30PM orbit, but are spaced a half orbit apart
  - Current strategies being considered include Earth invariant targets (deep convective clouds, deserts)
- Another option is using DSCOVER-EPIC as a transfer radiometer

DSCOVR EPIC imager

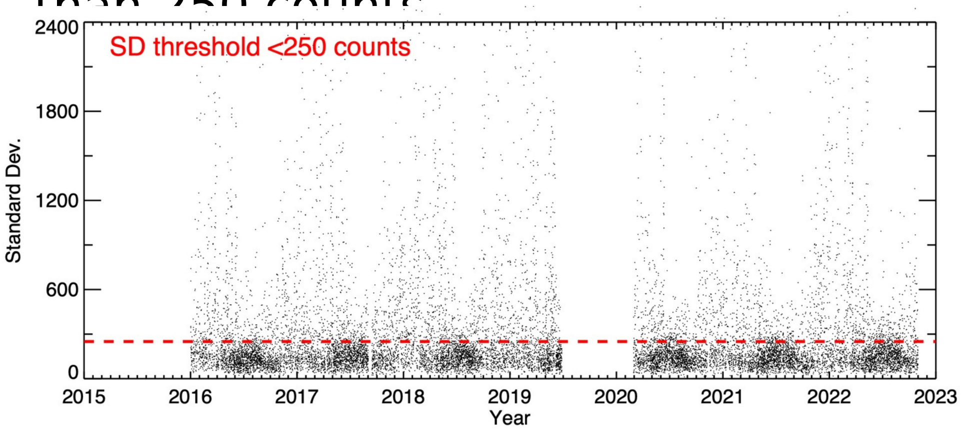
- The Deep Space Climate Observatory (DSCOVR) satellite is located at L1 about 1.5 million km from Earth
  - DSCOVR was launched in 2015 and is still operational today
- The Earth Polychromatic Imaging Camera (EPIC) instrument onboard DSCOVR is a CCD array that has a unique, constant view of the sunlit disk of the Earth
  - EPIC has 10 narrow channels ranging from UV to the NIR, including the 0.65µm channel, 18-km FOV at nadir
- EPIC captures 10-22 images of the Earth per day(depending on time of year)
  - This allows EPIC to be used as a transfer radiometer across many sun-synchronous local equator crossing time, including the NPP/NOAA-VIIRS sensors
- No onboard calibration systems
  - Need to verify that EPIC is stable over time, so that it does not introduce artifacts during radiometric scaling

Outline

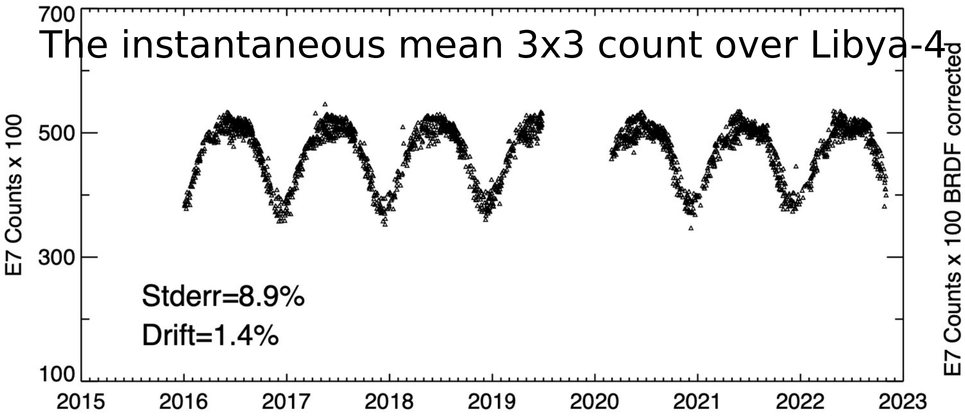
- Confirm EPIC 0.65µm stability based on
  - Libya-4 Desert Psuedo Invariant Calibration Site (PICS)
  - Deep Convective Cloud Invariant Target (DCC-IT)
- Inter-calibrate EPIC with NPP-VIIRS and N20-VIIRS utilizing coincident, collocated, and ray-matched radiance pairs
  - All-Sky Tropical Ocean Ray-matching (ATO-RM)
  - Deep Convective Cloud Ray-matching (DCC-RM)
- The inter-calibrated EPIC/VIIRS radiances is another check to validate EPIC stability
  - Assumes that VIIRS is stable
- Validate the NPP-VIIRS and N20-VIIRS radiometric scaling based on EPIC with those based on Aqua-MODIS
  - CERES currently uses Aqua-MODIS radiometric scaling factors
  - Once Aqua de-orbits, CERES plans on using EPIC to determine/validate the VIIRS pair radiometric scaling factors

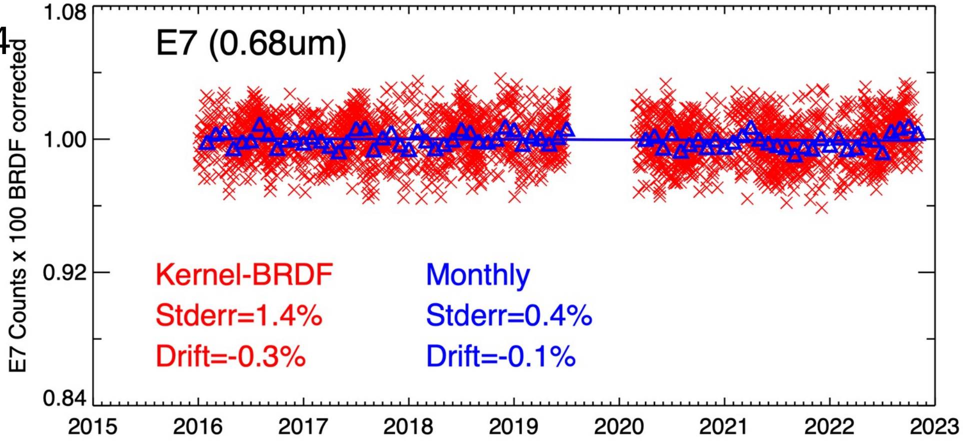
Libya-4 Desert EPIC PICS Methodology

- Libya-4 is a commonly used PICS due to its stability and lack of cloud cover
- Use near local noon EPIC images to increase the signal to noise ratio
- Remove cloudy events by limiting the 3 x 3 pixel standard deviation to less than 250 counts



Libya-4 Desert EPIC PICS Methodology





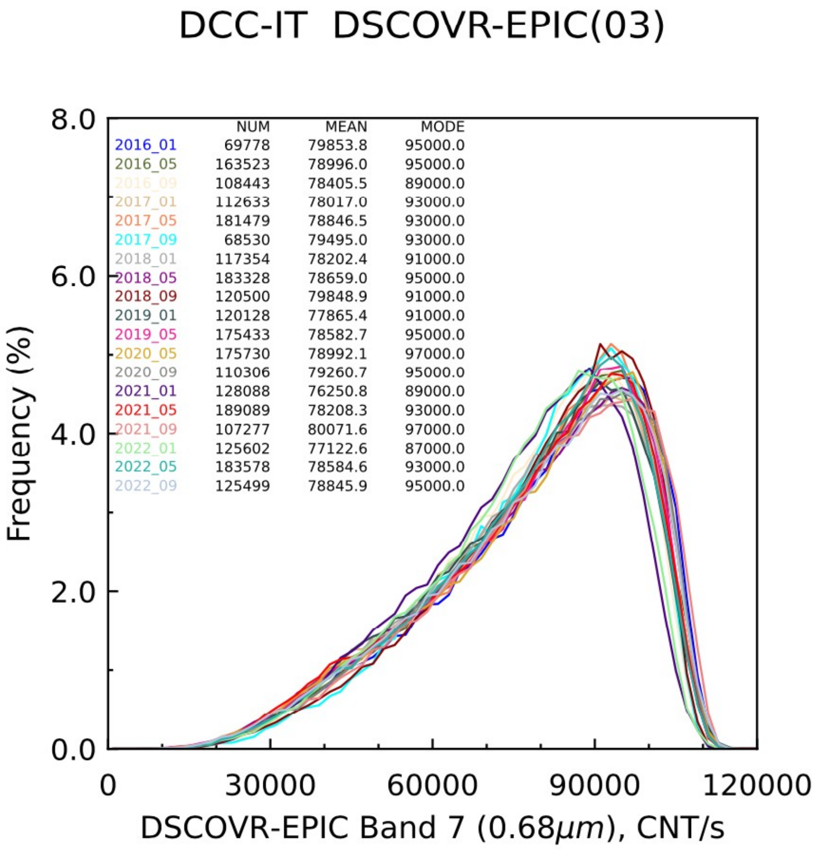
- Note the seasonal variation is due to the solar incoming seasonal cycle and the observed angular reflectance dependency
- Apply Roujean Kernal bidirectional reflectance distribution function (BRDF) model in order to remove angular effects

- The Roujean Kernal BRDF corrected instantaneous counts
- Average the corrected instantaneous counts over the month
- Libya-4 trend is -0.1% showing that EPIC band 7 is very stable

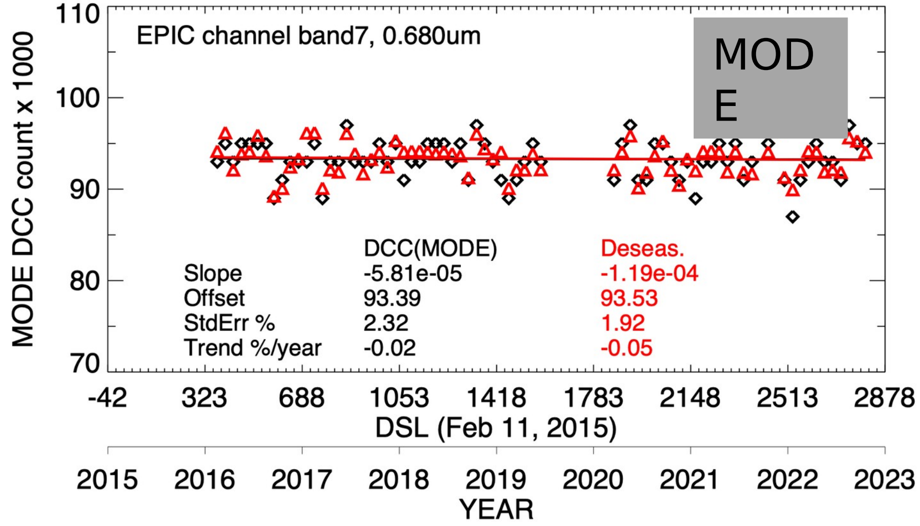
EPIC DCC Invariant Target Methodology

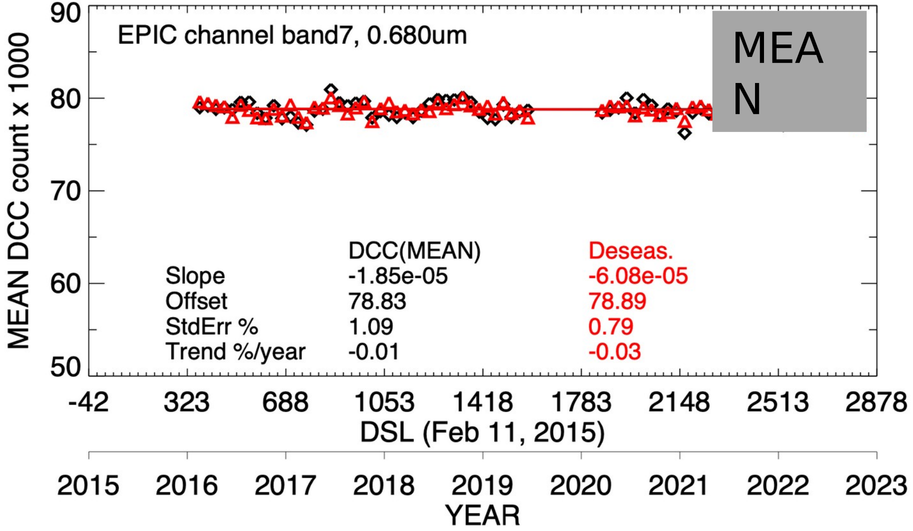
- Typically, an IR threshold is used to identify imager pixel DCC targets
  - EPIC does not have an IR channel
  - By matching EPIC and VIIRS coincident pixels, the VIIRS IR channel can then be used to identify EPIC DCC pixels

- Grid both EPIC and VIIRS pixels into a 0.25º latitude buy longitude grid
  - 0.25º grid is roughly the size of an EPIC pixel
  - Use a BT < 220 K to identify EPIC DCC pixels



Bin the EPIC DCC grid cell counts into monthly PDFs, and track the monthly mean and mode over time





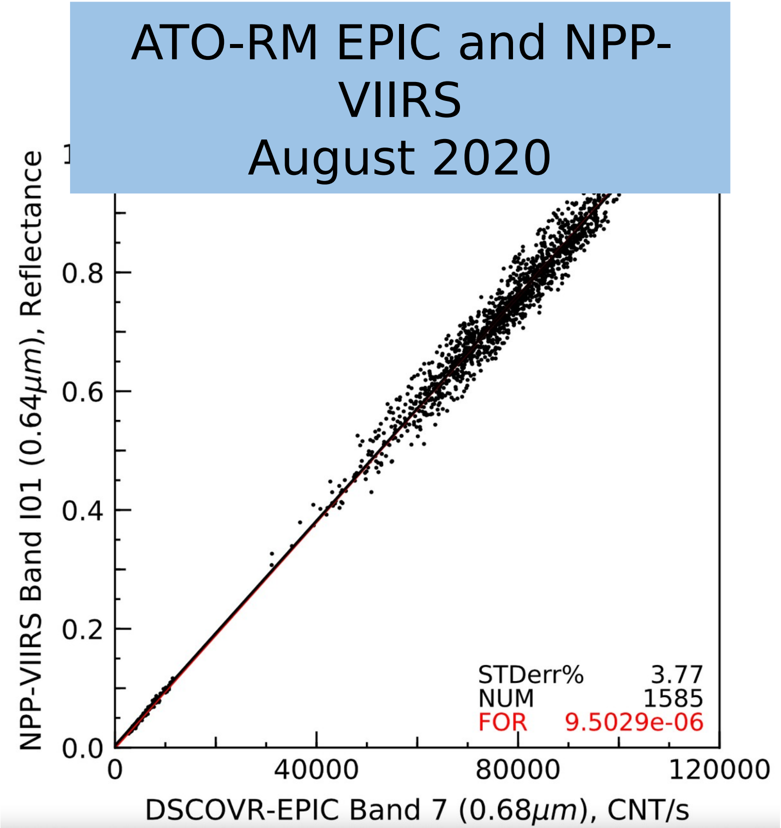
EPIC DCC-IT Methodology

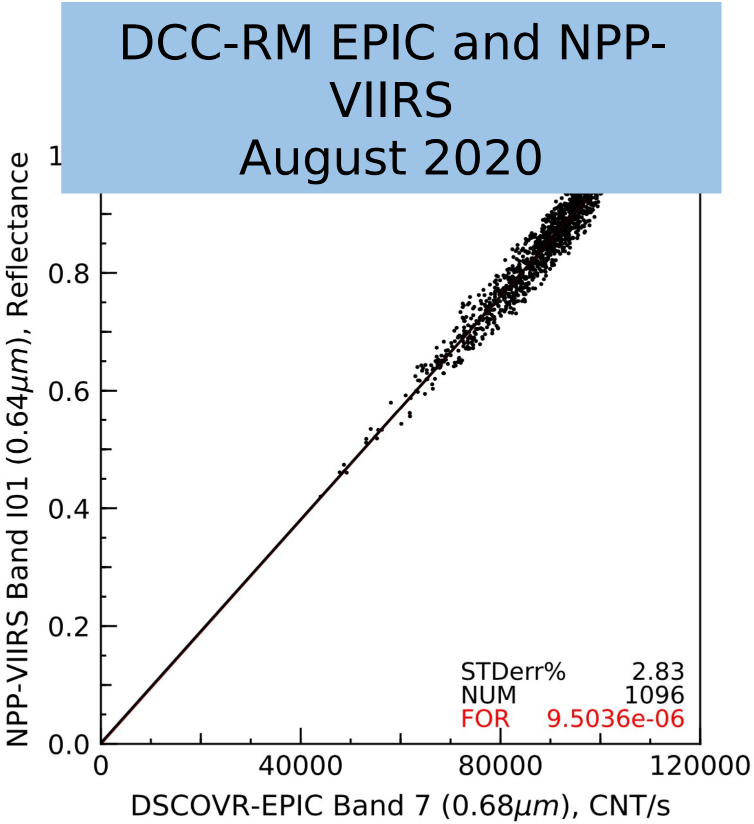
- The DCC mode count tracks the peak of the PDF, whereas the DCC mean count averages all of the DCC pixel counts in the PDF
- In this case, the PDF mode time series is much noisier than the mean, so use the mean to monitor the EPIC stability
- Deseaonalization of the monthly DCC counts further reduces the temporal linear trend standard error
- DCC-IT shows the EPIC band 7 (0.65um) trend to be about -

EPIC ATO-RM and DCC-RM

- Match EPIC with VIIRS in time, space, and angles
- Linearly regress EPIC/VIIRS radiance pairs on a monthly basis
- Monitor gains over time

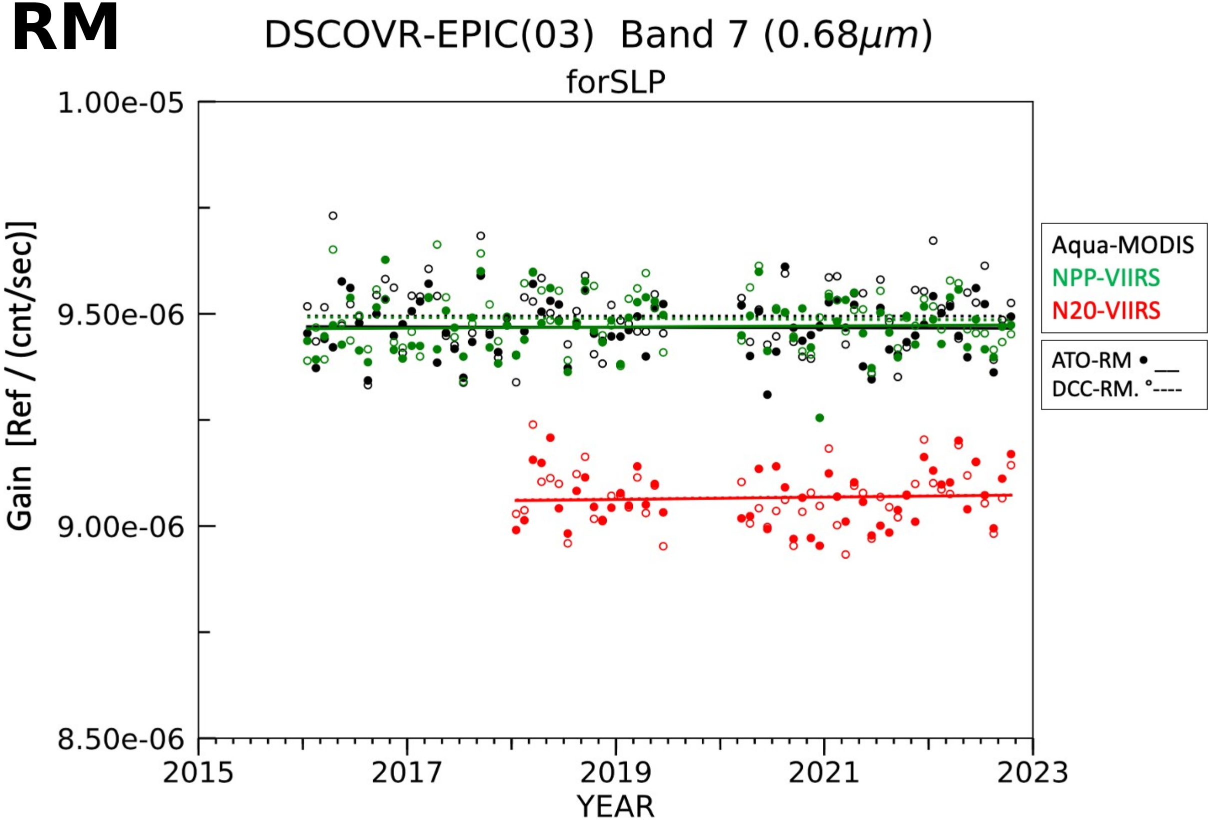
	ATO-RM	DCC-RM
Surface Type	Ocean	Land & Ocean
Grid Resolution	0.5º	0.25º
VZA	< 40º	< 40º
SZA	-	< 40º
ΔTime	< 15 minutes	< 15 minutes
ΔVZA	< 15º	< 15º
Δ(Scattering Angle)	< 15º	< 15º
ΔRAA	< 15º	< 25º
VIS Spatial Homogeneity ()	< 0.2	< 0.05
IR SDV	-	< 2.5
Graduated Angle Matching (GAM)	Yes	No
SBAF	Yes	Yes
11 µm BT	-	< 220 K





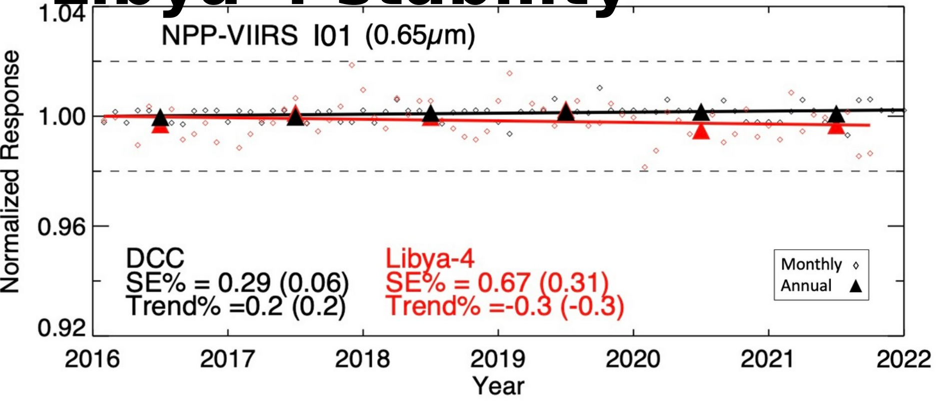
- ATO-RM gets a full dynamic range, while DCC-RM is limited to bright clouds
- Linearly regress through 0 (FOR) on a monthly basis
- Account for spectral differences by applying SCIAMACHY-based Spectral Band Adjustment Factors (SBAFS) – retrieved from:
  - https://satcorps.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SBAF

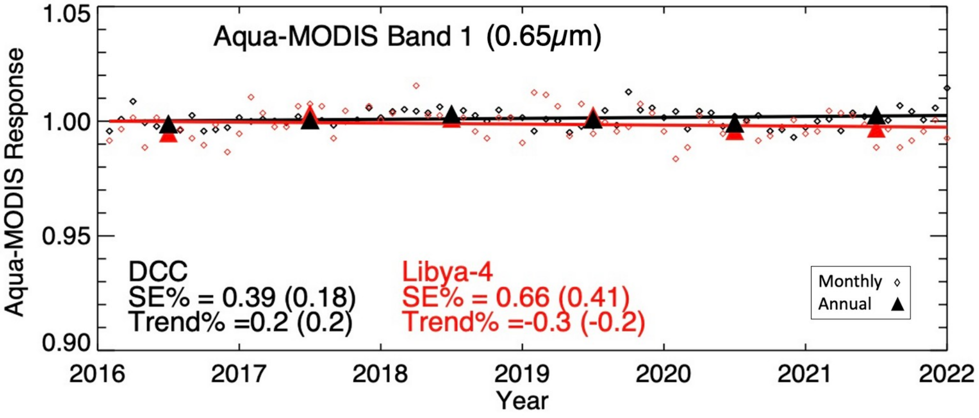
EPIC/VIIRS ATO-RM and DCC-RM

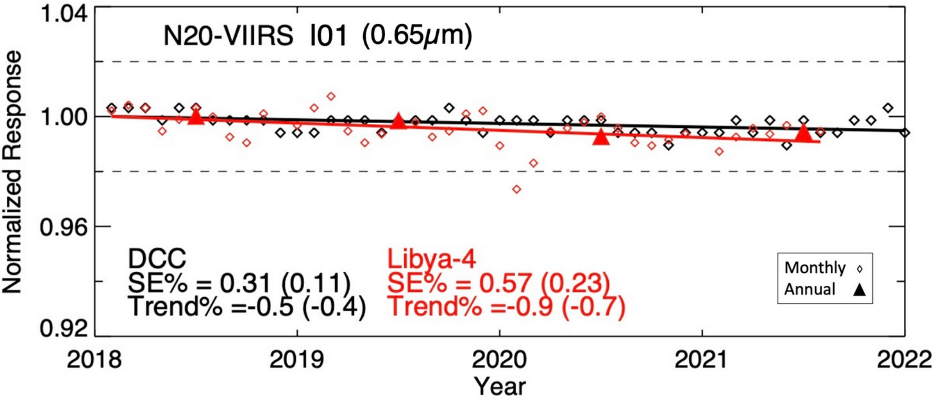


- ATO-RM and DCC-RM are mostly consistent
- EPIC and Aqua-MODIS, NPP-VIIRS and N20-VIIRS inter-calibration gains appear to be stable over time
- However, for ATO-RM and DCC-RM to truly be stable, both EPIC and the LEO imagers must be stable to begin with
- EPIC was shown to be stable earlier with the Libya-4 PICS and DCC-IT analysis

Aqua-MODIS, NPP-VIIRS and N20-VIIRS DCC and Libya-4 stability



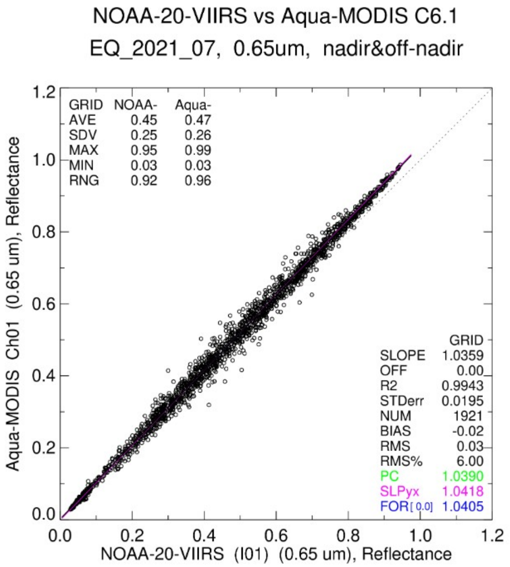


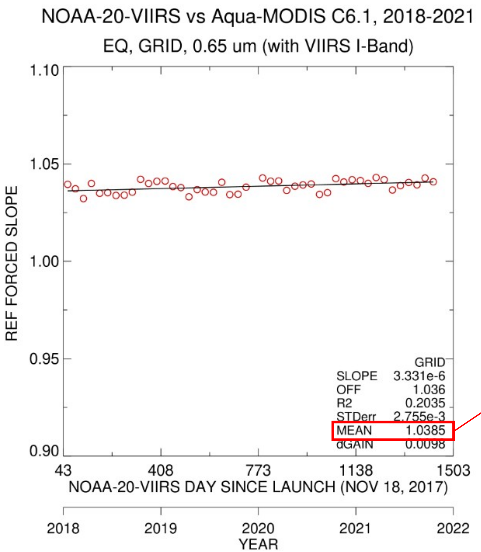


Independent Libya-4 and DCC-IT MODIS and VIIRS analysis shows that their records are stable, except for maybe a slight trend in NOAA-20 VIIRS

NASA CERES MODIS/VIIRS Radiometric Scaling

- The CERES project uses Aqua-MODIS C6.1 as a reference, and so NPP and NOAA-20 VIIRS need to be radiometrically scaled to that reference before being able to facilitate consistent clouds and fluxes
- These scaling factors are retrieved by performing ATO-RM between Aqua-MODIS and VIIRS L1B data during simultaneous nadir overpasses (SNOs)
- The mean gain of the monthly gains is the scaling factor





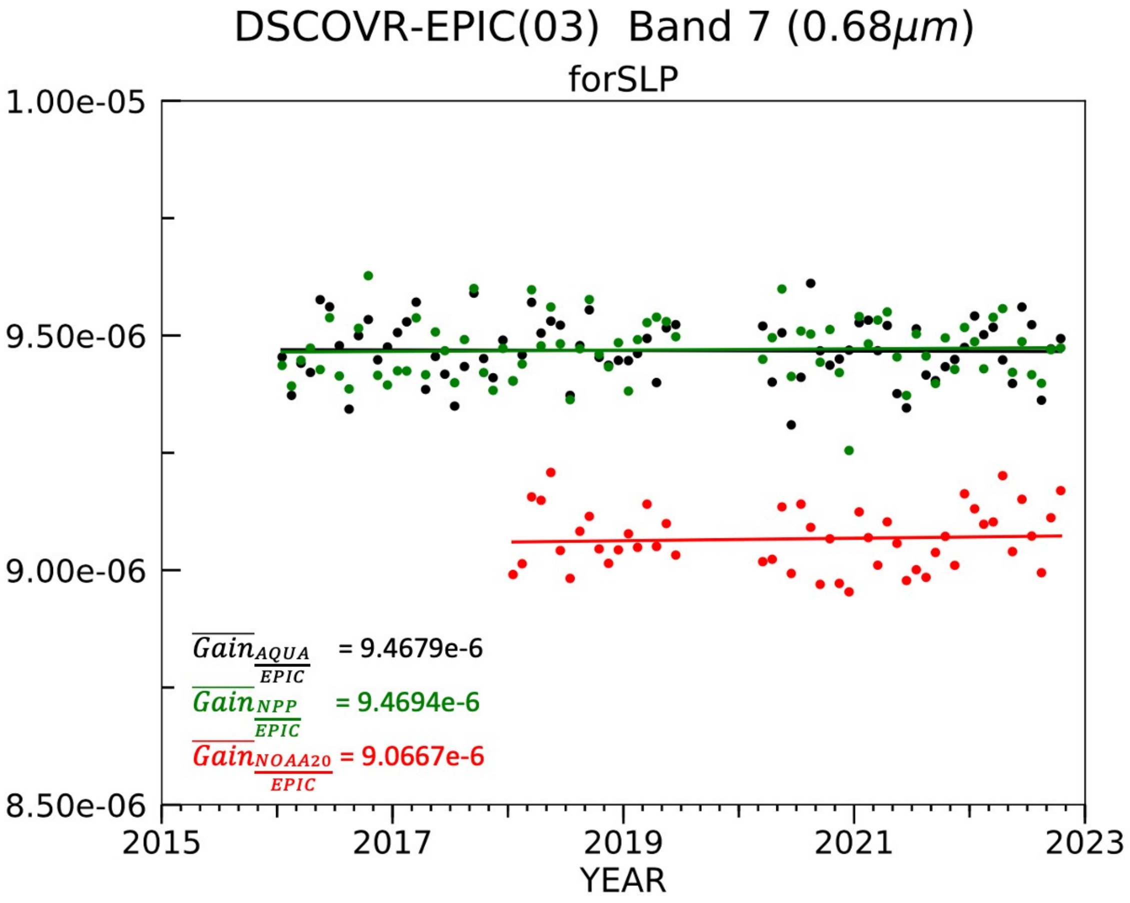
$$\overline{Gain}_{\frac{AQUA}{NOAA20}} = 1.0385$$

Validation of CERES MODIS/VIIRS Radiometric Scaling using EPIC

We can do a three-way validation between the EPIC ray-matching mean gains and the CERES-based mean gains

$$\underbrace{\overline{Gain}_{\frac{AQUA}{EPIC}} \;/\; \overline{Gain}_{\frac{NOAA20}{EPIC}}}_{\text{Mean gains from EPIC ATO-RM}} \;=?=\; \underbrace{\overline{Gain}_{\frac{AQUA}{NOAA20}}}_{\text{Mean gains from CERES-based ATO-RM}}$$

If the MODIS / VIIRS CERES-based gains are close to the EPIC-based gains, then that validates the CERES methodology for radiometric scaling



	CERES-based Gain	EPIC-based Gain	Diff (%)
Aqua / NPP	0.9904	0.9998	0.9
Aqua / N20	1.0385	1.0442	0.5

The table above shows that the EPIC-based gain or scaling factors and the CERES-based scaling factors are all within **1%** for the 0.65µm band, which validates this channel's CERES-based scaling factors, and also shows that EPIC can be used as a transfer radiometer when scaling

Conclusions and Future Work

- The DSCOVR EPIC instrument data can be used as an invariant target due to its stability – therefore EPIC can be used to monitor the sensor stability of other instruments
- The unique constant view of the sunlit side of the Earth allows EPIC observations to be inter-calibrated with many different sun-synchronous satellite instrument observations across the day
- EPIC can be used as a transfer radiometer for validating inter-sensor (MODIS/VIIRS) radiometric scaling factors for CERES for the 0.65µm channel
- This study is in the process of being performed for the other EPIC channels